

# Breathing and exchange of gases

## \* Breathing and respiration

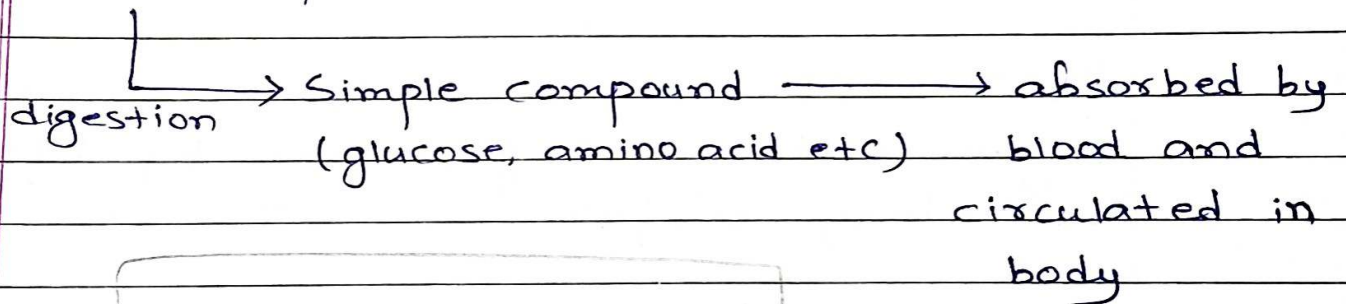
### Breathing

- physical process
- exchange of gas from atmosphere
- No ATP released
- Inhale + Exhale

### Respiration

- chemical process (catabolic)
- oxidation of food to release energy
- ATP + CO<sub>2</sub> released

- Food (complex)



↓ cell

↓ oxidation of glucose

- In our body, food is indirectly break down with the help of oxygen. In this process O<sub>2</sub> is used and energy is released. Also CO<sub>2</sub> is produced as by-product which is harmful for our body.

- In our body there is need to give oxygen regularly to the cells and to remove  $\text{CO}_2$  from the cells. This exchange of gas done by breathing.

### \* Respiratory organ

- Different animal have different respiratory organ depending on
  - (a) level of organization
  - (b) Habitat
- Lower invertebrate  $\rightarrow$  No respiratory organ, exchange of gas done by diffusion over body surface
- Annelida (earthworm)  $\rightarrow$  moist cuticle
- Insect  $\rightarrow$  Tracheal tube
- |              |   |       |
|--------------|---|-------|
| Fishes       | } | gills |
| mollusc      |   |       |
| Hemichordate |   |       |
- Amphibia  $\rightarrow$  lungs + moist skin
- |          |   |       |
|----------|---|-------|
| Birds    | } | lungs |
| Mammals  |   |       |
| Reptiles |   |       |



## \* Respiration (three types)

### (1) Branchial respiration

- Respiration done by gills
- eg: fish, aquatic amphibia

### (2) Pulmonary respiration

- Respiration done by gills lungs
- ex: mammal, birds, reptiles, terrestrial and amphibia

### (3) Cutaneous respiration

- By moist skin
- eg: frog

## \* Human respiratory system

### Sequence of human respiratory system

external nostril → nasal passage → nasal chamber → pharynx → larynx → trachea →  
1° bronchi → 2° bronchi → 3° bronchi →  
initial bronchiole → respiratory bronchiole  
→ terminal bronchiole → Alveoli

nasal chamber = Internal nostrils

### (1) External nostril

- one pair
- opening above upper lips through which air enter in body.

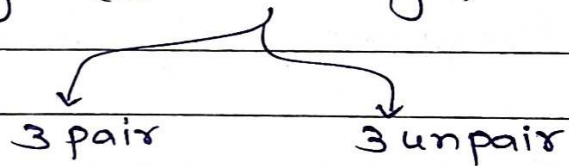
### (2) Air enter in nasal chamber through nasal passage

### (3) Pharynx

- Air from nasal chamber enters in pharynx
- pharynx has three parts
  - Oropharynx
  - Nasopharynx
  - Laryngopharynx

### (4) Larynx

- Voice box (help in sound production)
- made of cartilage (9 cartilage)



### (5) Trachea/Windpipe

- Straight tube (10-12 cm)
- At mid thoracic cavity (at T<sub>5</sub> vertebrae)
  - thoracic 5th

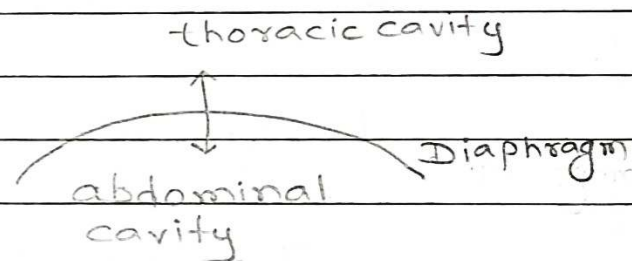
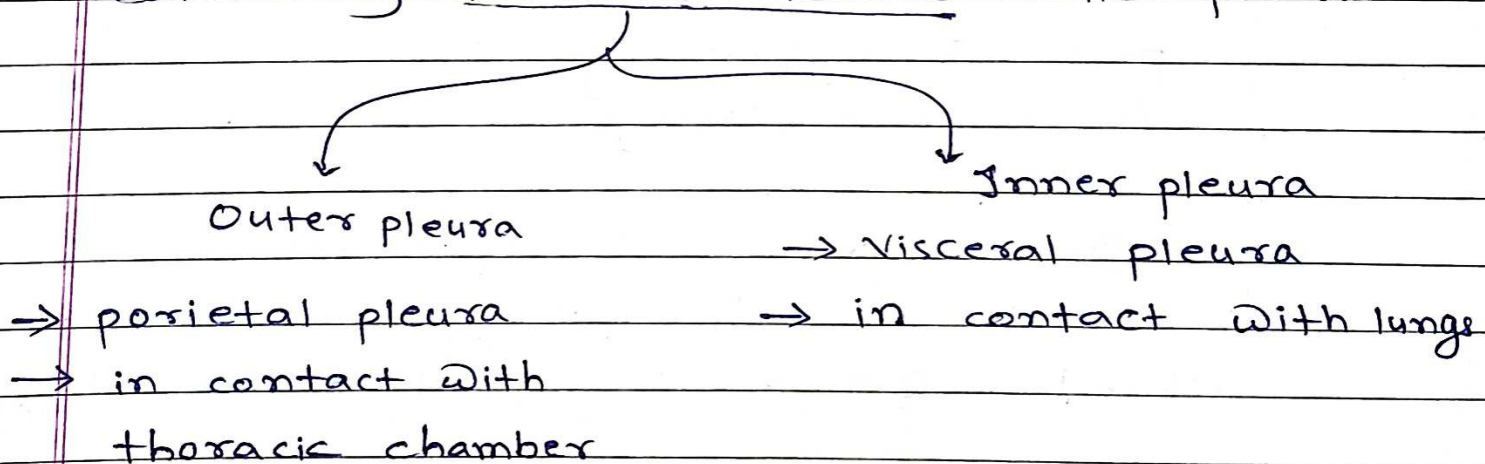


- Trachea divides into right and left - primary bronchi
- Right and left primary bronchi enters in right and left lungs respectively
- Dorsally incomplete c-shaped cartilaginous rings are ~~pre~~ present from trachea to initial bronchiole to prevent collapsing of tube

Note: Epiglottis is cartilaginous flap like structure that covers glottis (opening of trachea) during swallowing, so that food can't enter in trachea/windpipe

## (6) Lungs

- One pair
- Present in thoracic cavity
- Covered by double membrane called pleura



- In b/w outer pleura and inner pleura, pleural fluid is present which reduces friction

## Lungs

Right  
~~Left~~ lung.

- two fissure

↳ Oblique fissure

↳ Horizontal fissure

- three lobes

Superior, middle  
and inferior lobe

Left  
~~Right~~ lung

- one fissure

↳ Oblique fissure

- two lobes

Superior, inferior  
lobe

- Lungs are enclosed in air tight thoracic chamber

Dorsally → Vertebral column

Ventral → Sternum / breast bone

Laterally → Ribs

posterior → Diaphragm

Anterior → clavicle

Note: Our lungs can't contract or relax on its own. Any change in thoracic chamber will be reflected in our lungs



## \* Respiratory tract

### • Conduction part

→ From external nostril to respiratory bronchiole

function:-

- (a) transport air
- (b) filter air
- (c) humidify air
- (d) regulate tem. of air

### • Respiratory/Exchange part

- exchange of  $O_2$  and  $CO_2$
- from terminal bronchiole to alveoli  
(alveoli + alveolar duct)

## \* Five step of respiration

### (1) Breathing

→ Inhale of  $O_2$  rich air and exhale of  $CO_2$  rich air

### (2) Diffusion at alveoli

### (3) Transport of gases through blood

### (4) Diffusion at tissue

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(5) Using  $O_2$  by cell from oxidation of glucose to produce energy. in this process  $CO_2$  is produced.

\* Mechanism of breathing  
Breathing involves in two stages

(1) Inspiration

→ Atmospheric air is drawn in the body

(2) Expiration

→ Alveolar air is released out in atmosphere here

→ Breathing is done by creating - pressure gradient b/w atmosphere and lungs.

Note:  $p \propto \frac{1}{V}$

air will move from high pressure to low pressure.

\* Muscle involved in breathing

(1) Intercoastal muscle (2) Abdominal muscle



### <1> Intercoastal muscle

- B/w ribs
- two types

(a) External intercoastal muscle (EICM)  
↳ normal breathing

(b) Internal intercoastal muscle (IICM)  
↳ forceful breathing

### (2) Abdominal muscle

→ Involved in forceful breathing

### \* Mechanism of inspiration

#### (1) Diaphragm

Diaphragm contract → Volume increase in  
AP axis  
↳ anterior - posterior axis

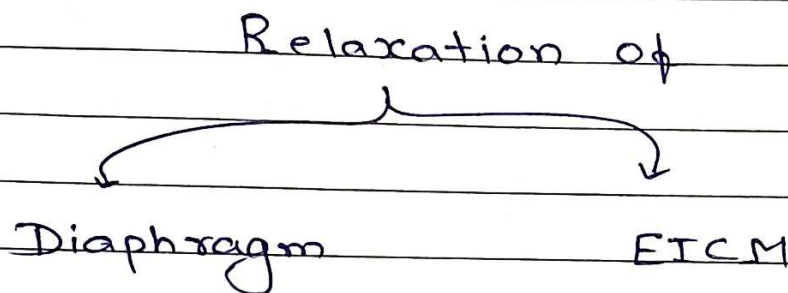
#### (2) External intercoastal muscle

EICM contract → Volume increase in  
DV axis  
↳ dorsal - ventral axis

Overall, Volume increase in thoracic cavity as well as inside lungs. pressure inside lungs (intra-pulmonary pressure) decreases.

Air will move from high pressure to low pressure (from atmosphere to lungs). Inspiration done.

### \* Mechanism of expiration



- Diaphragm, ribs and sternum get back to their original position
- Volume of thoracic chamber decrease, similarly pulmonary volume decreases hence, intra-pulmonary pressure increases above atmospheric pressure
- Now air will move from high pressure to low pressure (from lungs to atmosphere)
- Expiration done



- Spirometer is used to know pulmonary function and ~~their~~<sup>for</sup> diagnostic purpose

- A healthy person breathe around 12-16 times/minute

- Note: Inspiration = active process (2 sec)  
Expiration = passive process (3 sec)

### \* Respiratory volume

#### (1) Tidal volume

Volume of air inspired or expired during normal respiration.

→ 500ml

→ 1 min ÷ 6-8L

#### (2) Inspiration reserve volume

Additional volume of air a person can inhale during forceful inhalation.

→ 2500-3000 ml

#### (3) Expiratory reserve volume

Additional volume of air a person can exhale during forceful exhalation

→ 1000-1100 ml

#### (4) Residual volume

- Amount of air that always remain in lungs

→ 1100 - 1200 ml

#### \* Respiratory capacity

- By adding respiratory volume we get respiratory capacity.

#### (1) Inspiratory capacity

- Total amount of air a person can breathe in after normal expiration

→  $IRV + TV$

#### (2) Expiratory capacity

- Total amount of air a person can breathe out after normal inspiration

→  $TV + ERV$

#### (3) Functional residual capacity

- Amount of air remaining in lungs after normal expiration.

→  $ERV + RV$



#### (4) Vital capacity

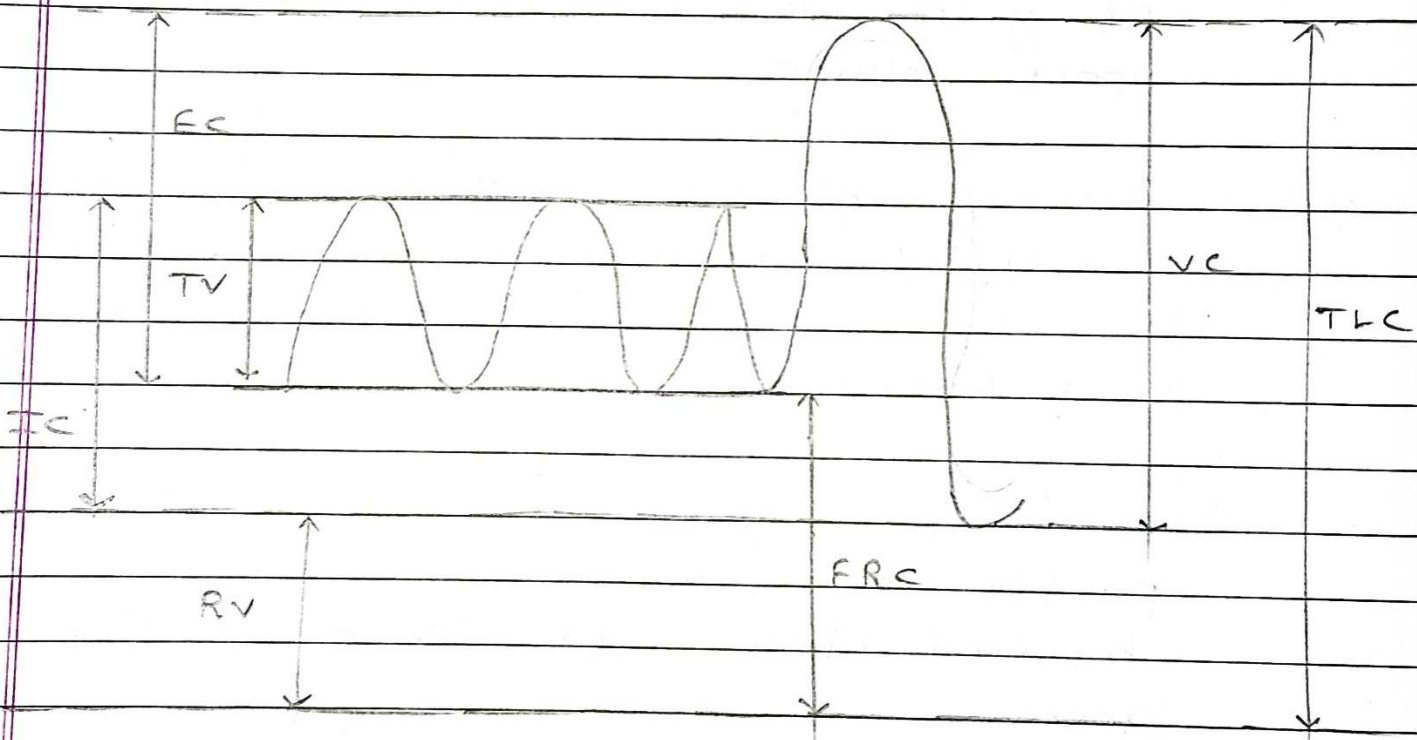
- Total amount of air a person can exhale after forceful inspiration.

→  $TV + ER + IRV$

#### (5) Total lungs capacity

- Total amount of air that can accomadate in lungs after forceful inspiration.

→  $TLC = VC + RV$  or  $IRV + TV + RV + ERV$



Graph of respiratory volume and capacity

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Note:- Spirometer can't measure residual vol. and total lungs capacity

### \* Anatomical dead space

- Total amount of air inhaled but doesn't participate in exchange of gas
- 150ml of air remained trapped in respiratory pathway, this portion of air which doesn't participate in exchange of gases is called anatomical dead space volume.
- Amount of air available for exchange  
= Tidal volume - anatomical dead space volume.  
=  $500 - 150 = 350\text{ml}$

### \* partial pressure

partial pressure is the pressure exerted by individual gas in a mixture of gases

$p_{O_2} \rightarrow$  partial pressure of  $O_2$

$p_{CO_2} \rightarrow$  partial pressure of  $CO_2$



## \* Exchange of gas

In our body, diffusion occurs at two places

(1) At alveoli

$O_2 \rightarrow$  from alveoli to capillary

$CO_2 \rightarrow$  from capillary to alveoli

(2) At tissue

$O_2 \rightarrow$  from blood capillary to tissue

$CO_2 \rightarrow$  from tissue to blood capillary

Note: Air will always move from high pressure to low pressure.

|        | Atm. air | Alveoli | deoxy blood | oxy. blood | Tissue |
|--------|----------|---------|-------------|------------|--------|
| $PO_2$ | 159      | 104     | 40          | 95         | 40     |
| $CO_2$ | 0.3      | 40      | 45          | 40         | 45     |

mmHg is the unit of pressure

In alveoli, cells are known as pneumocyte  
It is of two types

• Type-I pneumocyte

$\hookrightarrow$  exchange of gases

## • Type-II pneumocyte

↳ produce lecithin (phospholipid) which act as surfactant, reduce surface tension.

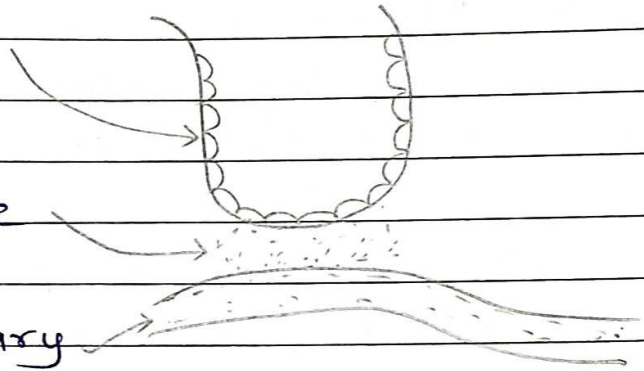
## \* Diffusion membrane

• Made of three layers

(a) Epithelium of alveoli  
(simple squamous)

(b) Basement membrane

(c) Endothelium of capillary  
(simple squamous)



note: Diffusion membrane is less than 1mm

## \* Factor affecting rate of diffusion

(i) Solubility of gas → directly proportional

(ii) Thickness of membrane → inversely proportional

(iii) partial pressure of gas → directly proportional



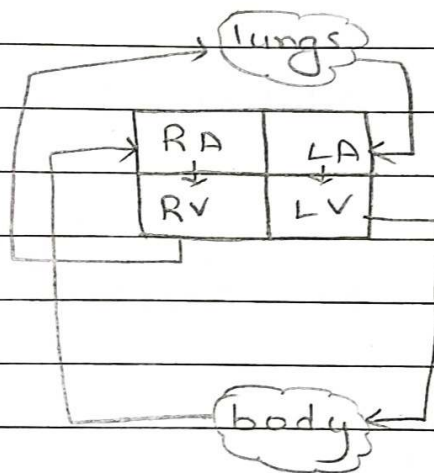
Note:  $\text{CO}_2$  is more soluble than  $\text{O}_2$  (20-25 times)

•  $\text{O}_2$

↳ alveoli → blood → tissue

•  $\text{CO}_2$

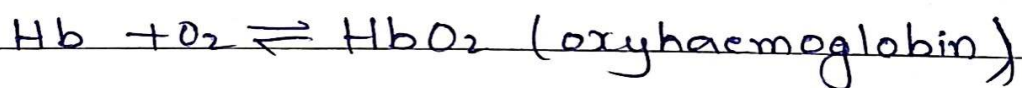
↳ tissue → blood → alveoli



\* Transport of gas

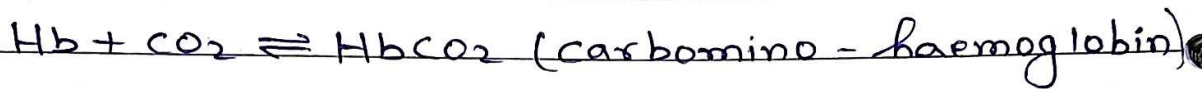
• Oxygen

97% as oxyhaemoglobin      3% dissolved in plasma



## • Carbon-dioxide

|                     |                        |                           |
|---------------------|------------------------|---------------------------|
| 70%.                | 7%.                    | 20-25%.                   |
| as $\text{HCO}_3^-$ | dissolved<br>in plasma | carbomino-<br>haemoglobin |



## \* Transport of oxygen

### Haemoglobin

- ↳ quaternary protein
- ↳ made up 4 chain
- ↳ adult haemoglobin  
 $2\alpha, 2\beta (\alpha_2, \beta_2)$
- ↳ fetus haemoglobin  
 $2\alpha, 2\gamma \text{ chain } (\alpha_2, \gamma_2)$

- Haemoglobin is ~~red~~ iron containing red colour pigment in RBC

Note: HbF is more oxygen loving than HbA



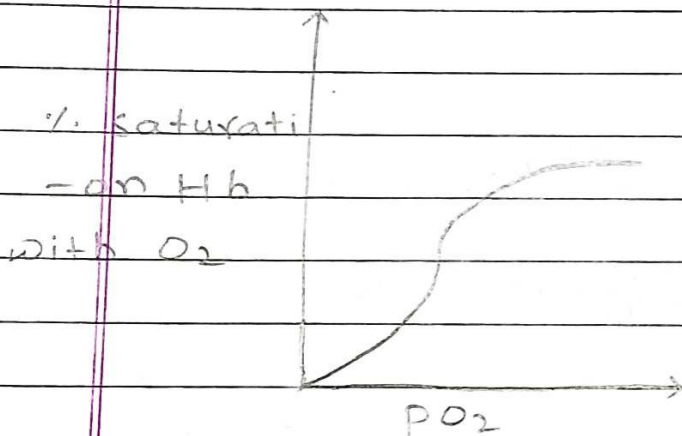
## \* Factor affecting binding of Hb with $O_2$

- (a)  $PO_2$  (b)  $PCO_2$  (c)  $H^+$  concentration/pH  
(d) temperature

## \* Oxygen dissociation curve

Graph plotted b/w partial pressure of oxygen and percentage saturation of haemoglobin with oxygen.

→ Sigmoid in shape (S-shaped)



## \* Shifting of $O_2$ dissociation curve

Right shift

Left shift

→ At tissue

→ At alveoli

→ Dissociation of  $O_2$  from oxyhaemoglobin;

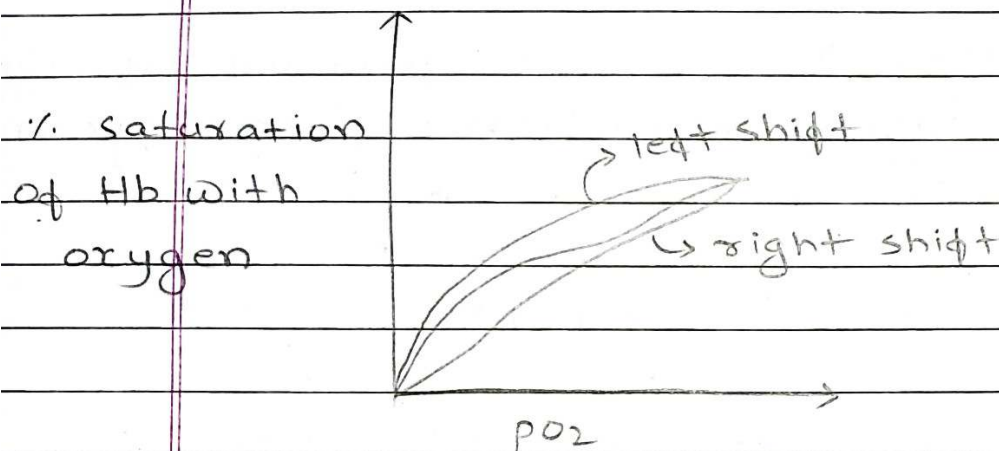
→ promote association of  $O_2$  with Hb to form oxyhaemoglobin.

Right shift

$PO_2 \downarrow$   
 $PCO_2 \uparrow$   
 $H^+ \uparrow (pH \downarrow)$   
 $temp \uparrow$

Left shift

$PO_2 \uparrow$   
 $PCO_2 \downarrow$   
 $H^+ \downarrow (pH \uparrow)$   
 $temp \downarrow$



100ml of oxygen blood + 20ml deliver to tissue

normal  
condition  
5ml

stress  
condition  
15ml

1Hb = 4O<sub>2</sub> → 100% saturated

1Hb = 3O<sub>2</sub> → 75% "

1Hb = 2O<sub>2</sub> → 50% "

1Hb = 1O<sub>2</sub> → 25% "



- $P_{50} \rightarrow$  partial pressure of oxygen at which haemoglobin is 50% saturated with  $O_2$   
 $\rightarrow$  It is around 26.9 mmHg

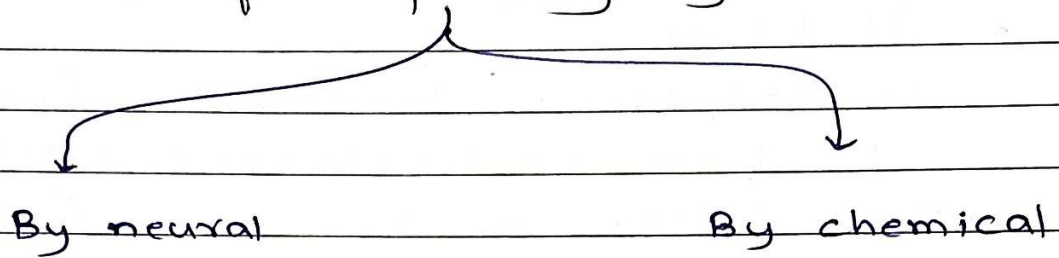
## \* Transport of $CO_2$

- At tissue
  - 20-25% of  $CO_2$  bind with hemoglobin (Hb) to form carbaminohaemoglobin ( $HbCO_2$ )
  - 7% of  $CO_2$  dissolves in plasma
  - 70% of  $CO_2$  enters RBCs. Inside RBCs,  $CO_2$  reacts with water ( $H_2O$ ) to form carbonic acid ( $H_2CO_3$ ) via the enzyme carbonic anhydrase (CA).  $H_2CO_3$  dissociates into  $H^+$  and  $HCO_3^-$  (bicarbonate ions)
  - Chloride shift (Hamburger's phenomenon)  
 $\rightarrow HCO_3^-$  exits RBCs, and  $Cl^-$  ions enter to maintain ionic balance
  - $\Delta$   $HCO_3^-$  enters in plasma, in plasma  $HCO_3^-$  combines with  $Na^+$  to form  $NaHCO_3$
- At alveoli  
 $\rightarrow$  The reverse process occurs!
  - Reverse chloride shift:  $Cl^-$  exist RBCs as  $HCO_3^-$  enters.

•  $\text{HCO}_3^-$  converts back to  $\text{H}_2\text{CO}_3$ . While dissociates into  $\text{CO}_2$  and  $\text{H}_2\text{O}$

•  $\text{CO}_2$  diffuses into alveoli and is exhaled

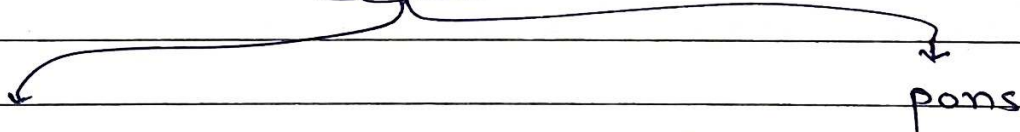
### \* Regulation of respiratory system



### \* Regulation Neural regulation of respiratory system

→ Regulation controlled by ~~brain~~ brain

Brain



Medulla oblongata

has RBE RRC

(respiratory rhythm - centre)

has pneumotaxic centre

• it reduces duration of inspiration

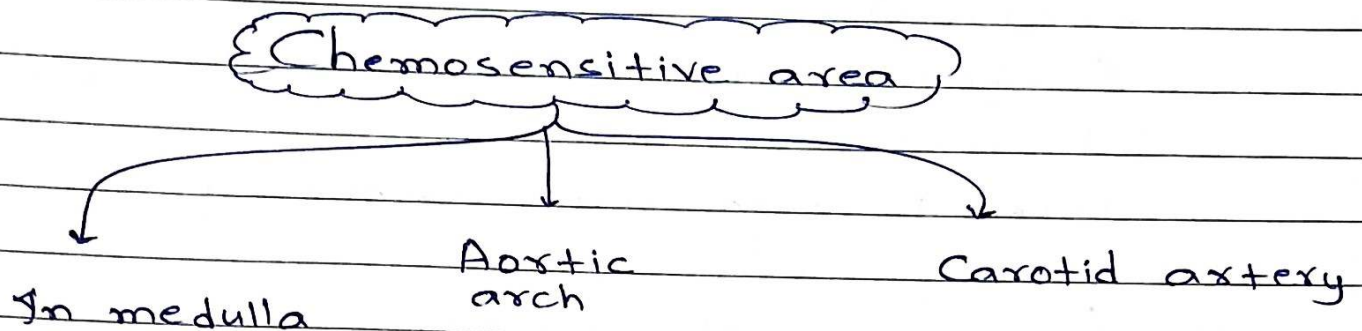
• signal to RRC

It includes DRG and

VRG



\* Chemical regulation of respiratory system  
Chemosensitive area sensitive to chemical like  $\text{CO}_2$  and  $\text{H}^+$  is present in our body



As  $\text{CO}_2$  and  $\text{H}^+$  rises in body  
↓  
these chemosensitive area get activated  
↓  
Message sent to RBC

Note: Oxygen has no significant role in regulation of respiration (only  $\text{CO}_2$  and  $\text{H}^+$  do this)

\* Disorders of respiratory system

(1) Asthma

- Inflammation of bronchi and bronchiole
- Difficulty in breathing
- Wheezing sound during breathing

## (2) Emphysema

- Alveolar wall is damaged (due to trypsin - enzyme)
- Surface area for exchange of gases decreases
- Due to cigarette smoking

## (3) Occupational respiratory disorder

- It includes industries of stone-breaking or grinding.

- Small dust particles produced are inhaled by workers which cause fibrosis or proliferation of lungs

ex: Silicosis (due to silica)

Asbestosis (due to asbestos)

- Wearing mask is advised to workers